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Rare-earth elements market: A historical and financial perspective

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ABSTRACT

Rare earth elements (REEs), which include the lanthanides, yttrium, and scandium, have been the focus of several studies in recent years due to their contribution to modern technology (e.g. screens of smart phones, computers, and flat panel televisions; batteries of hybrid and electric cars), China's dominance in production and consumption, and to the international dependence on China for most of the world's REE supply.

The aim of this study is two-fold. First, to offer a historical perspective of the REE market by constructing and analyzing time series of consumption, production, and oxide/metal prices. Such series are mostly non-existent (e.g., consumption) or scattered across different sources (e.g., prices). Second, to provide a financial perspective of the REE market by gauging the market capitalization and systematic risk of leading companies involved in exploration, production and processing of REEs worldwide; and, by measuring co-movement of REE prices and commodity indices. We contribute to the existing literature by providing a thorough overview of the REE market.

1. Introduction

A strategic mineral may be defined as one that is important to a nation's economy, particularly for defense issues; it does not have many substitutes; and it primarily comes from foreign countries. The strategic term usually reflects a nation's perception of vulnerability to supply disruptions, and of a need to protect its industries from repercussions of a loss of supplies. Nowadays rare-earth elements (REEs) are considered strategic minerals, along with gallium (a silvery metal used in semiconductors) and manganese (a metal alloying ingredient), among others (Ishee et al., 2013).

In particular, REEs are comprised of the lanthanides (atomic numbers 57–71), yttrium (atomic number 39) and scandium (atomic number 21). On the basis of their atomic weight, REEs are divided into light REEs (LREE)— lanthanum through gadolinium (atomics numbers 57–64), and heavy REEs (HREE)—terbium through lutetium (atomic number 65 to 71). Yttrium is also considered as HREE because of its similar chemical and physical properties to the elements of that group. REEs receive this name because, given the existent technology, they are generally not concentrated in commercially viable quantities and due to the complexity of their separation process. (See, for instance, Van Gosen et al., 2014; Laurent, 2014).[2] However, some REEs may be more common than industrial metals, such as copper and lead, and precious metals, such as gold and silver. For instance, the crust abundance of cerium, neodymium, and lanthanum is 62, 60, and 57 ppm (ppm), respectively, as opposed to 60, 13, 0.004 and 0.075 ppm of copper, lead, gold, and silver, respectively (Van Gosen et al., 2014).

The main semi-final industries using LREE (i.e., lanthanum, cerium, praseodymium, neodymium, samarium, and europium), are permanent magnets, phosphors (i.e., substances that emit luminescence), battery alloy, fluid catalytic cracking, ceramics, glass additives, polishing powders, auto catalysts, and metallurgy excluding batteries. Cerium and lanthanum are used in almost all of these industries, while samarium and europium are limited to phosphors and battery alloy. In turn, the main semi-final industries using HREE (i.e., terbium, dysprosium, yttrium, and others) are permanent magnets,[3] ceramics, phosphors, and glass additives (Laurent, 2014). In particular, yttrium plays an essential role in the production process of ceramics and phosphors (i.e., light bulbs, panels, and televisions).

According to the US Geological Service (USGS) Mineral Commodity Summaries 2016, REE reserves worldwide are estimated to be 130 million tons. China and Brazil hold the largest shares of such reserves with corresponding figures of 16.9% and 42.3%, followed by Australia,

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[2] However, this classification is not unique as, for instance, europium and gadolinium (atomic numbers 63 and 64, respectively) may be included within HREE (Van Gosen et al., 2014). On the other hand, the Ministry of Land and Resources of China sometimes refers to samarium, europium and gadolinium (atomic numbers 62 through 64, respectively) as medium rare-earth elements (MREE) (Liu et al., 2016).

[3] Rare-earth magnets, which are stronger than any other magnet type, are used in computer hard disks and CD/DVD disk drivers, and clean–energy technologies, such as wind turbines and electric vehicles (Van Gosen et al., 2014).

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India, and the United States with corresponding shares of 2.5%, 2.4%, and 1.4%. The US and world REE resources, typically of LREE, are primarily contained in bastnäsite, a REE-carbonate-fluorine mineral, and monazite, a REE-thorium-phosphate mineral.

Bastnäsite deposits in China and the United States represent the largest percentage of REE economic resources worldwide, while monazite-xenotime deposits,[4] located in Australia, Brazil, China, India, Malaysia, and South Africa, are the second largest source. REE deposits can also occur in other two geological environments: alkaline igneous rocks and ion-absorption clay deposits. The latter, located in southern China and named "south China clays", are currently the world's largest source of HREE (Van Gosen et al., 2014). Table 1 presents some statistics on rare-earth contents of selected source minerals from the USGS. As can be seen, among LREE, lanthanum and cerium are the most abundant, followed by neodymium. By contrast HREE are considerably scarcer, with the exception of yttrium.

Regarding mine production, the USGS Mineral Commodity Summaries 2016 shows that, out of the 124,000 metric tons estimated to have been produced in 2015, China contributed with 87.5%,[5] followed by Australia (8.3%), the United States (3.4%), Russia (2.1%), Thailand (1.7%), and Malaysia (0.2%).[6] Furthermore, China's predominance was not limited to supply, as its share of world consumption was around 60% in 2015. The remaining 40% was split half between the United States/Europe and the rest of Asia, whose largest consumer is Japan (Laurent, 2014). Specifically, China's consumption in 2015 was led by magnets (35%), abrasives (18%), and catalysts (15%). The China's Rare Earth Industry Association estimates that China's REE consumption will increase from 98,000 t in 2015 to 149,000 t in 2020. That is, an annual increase of around 8.7% (USGS Mineral Commodity Summaries 2016).

An issue associated to mining and processing of rare earths is the environmental damage caused by radioactive waste from thorium present in the ores, which can contaminate water and air. One reason that China has captured the largest share of production and processing of REEs is because of its willingness to accept the associated environmental damage over the years (Campbell, 2014). An example of environmental cost associated to REE mining in China is the water pollution involving the Yellow, Jinsha, Huaihe, Yangtze, and Pearl Rivers. In particular, rare earth mining activities are most intensive in the Pearl River Basin due in part to Ganzhou's REE development, known as the Capital of Rare Earths (Liu et al., 2016).

Recent literature on REEs include, among others, Mancheri et al. (2013), who extensively analyze the dominant position of China in the REE market not only in raw materials but also in intermediate inputs utilized at a later stage in high-technology industries; Massari and Ruberti (2013), Machacek and Fold (2014), and Campbell (2014), who highlight China's predominant role in world REE supply, the very few effective substitutes of REE, and the need for developing REE processing and use capacity outside China[7]; Mancheri and Marukawa (2016) who provide a comprehensive study of the REE industry from mining to final products, the role of China and Japan regarding REE supply/demand, and the price mechanism and its impact on the Japanese manufacturing sector; He et al. (2014) and Ge et al. (2016), who study an optimal trading partnership for China in the REE world market, and analyze competing and complementary relationships between major REE trading countries[8]; Mancheri (2015) who evaluates the impact of China's REE exports restrictions on international markets; Schlinkert and van den Boogaart (2015) who develop a four-stage model—penetration of the market, exploiting market power, losing market, and transformation of the market—to understand the transformation of the REE market from China's monopoly to a polypoly[9]; Wang et al. (2015), who utilize a model from the exhaustive resources literature to forecast China's REE production; and, Paulick and Machacek (2017), who analyze the surge in REE exploration activities carried out by junior exploration companies following the REE price peak of 2011.[10]

This article is somehow connected with those of Campbell (2014), Mancheri (2015) and Ge et al. (2016), in that it also offers a big picture of the REE market. However, it distinguishes from these studies by providing a comprehensive historical perspective of REE prices, consumption, and production. In particular, one contribution of this study is to compute REE consumption series for selected countries from information of the United Nations Commodity Trade (UN Comtrade) Statistics Database. Indeed, REE consumption statistics are publicly available only for the United States from the USGS. A second contribution of this study is to offer a financial perspective of the REE market by computing market capitalization of key REE mining companies, gauging the systematic risk of their stock shares relative to relevant market indices, and by measuring co-movement of REEs prices and selected commodity indices. Such a perspective appears as relevant to portfolio managers, as REE arise as another investment vehicle.

This article is organized is as follows. Section 2 presents the data and methodology. Section 3 in turn analyzes consumption and production statistics. Production is gathered from the USGS, whereas consumption is computed as apparent consumption from the UN Comtrade Statistics Database for various countries. Section 4 presents annual time series of oxide and metal prices from the USGS. More recent price data is obtained from the Shanghai Steelhome E-Commerce at a monthly frequency. In addition to annual oxide/metal prices, annual imports/exports unit values are computed from the UN Comtrade Statistics Database. Section 5 offers a financial portrait of the REE market by analyzing the evolution of market capitalization of companies involved in exploration, production and processing of REEs, computing the systematic risk of selected companies, and by analyzing co-movement of returns on REE prices and selected commodity indices. Section 6 closes by presenting the main findings of this study.

2. Data and methodology

2.1. Data

This study utilizes three main information sources for the discussion presented in Sections 3 through 5: (i) USGS: rare-earth oxide (REO) equivalent production and annual REO and metal/oxide prices; (ii) UN Comtrade Statistics Database: exports and imports of REE-related items, and (iii) Bloomberg: Shanghai Steelhome E-Commerce's monthly REE prices; selected commodity indices; and, market capitalization of leading REE companies.

[4] Xenotime, a more marginal source of REE than monazite, is a source of yttrium and other REEs.

[5] This figure does not include undocumented production. Indeed, illegal mining and trafficking of REEs is a pervasive problem in China (see, for instance, Mancheri, 2015; Liu et al., 2016).

[6] This figure is quite small when compared with the yearly mine production of industrial metals such as copper. According to the World Metals Statistics 2015 Yearbook, the world mine production of copper reached 18,497 thousand metric tons in 2014.

[7] Embso et al. (2015) analyzed 23 sedimentary phosphate deposits (phosphorites) in the United States and found that they are significantly enriched in REEs. In Embso et al.'s view such phosphorites might ease the global REE supply shortage, particularly for HREE.

[8] In particular, based on trading data for the period of 2011–2015, Ge et al. found that the 146 REE-trading countries formed three trade communities, where the one led by the United States, China, Japan, and Germany had the greatest effect on world REE trade.

[9] Such current monopoly has raised concerns that China may deplete its REE resources too quickly with the subsequent supply disruption in the rest of the world (Mancheri, 2012).

[10] Related literature has analyzed world resources (e.g., Zhanheng, 2011; Machacek and Kalvig, 2016).